Detection of Rain-On-Snow events in the Canadian Arctic from passive microwave data

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1 • Introduction

Climate change impacts the Arctic:

- Increasing temperatures over the past 100 years [IPCC, 2013]
- Increasing sea level rise
- Negatives anomalies of snow cover and sea ice extent
- Modification of the seasonal snow cover:
  - Suface energy balance [Dethloff and al., 2006]
  - Albedo and thermal conductivity [Lemke and al., 2007]
  - Hydrology (freshwater reservoir) [Barnett and al., 2005]
  - Impacts of permafrost regimes [Remanovsky and al., 2010]
- Increasing occurrence of winter extreme events such as heat waves and **Rain-On-Snow (ROS)**

- Little known about ROS
- Cumulative impacts on the surface energy balance remains unknown
- Formation of ice crust after ROS:

Water percolation
Accumulation of water at the bottom of the snowpack
After cooling forms an ice crust

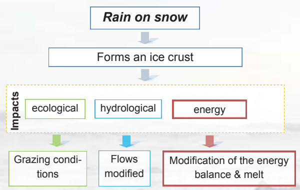


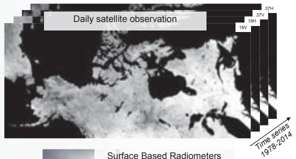
Figure 1: Flow chart of ROS events consequences

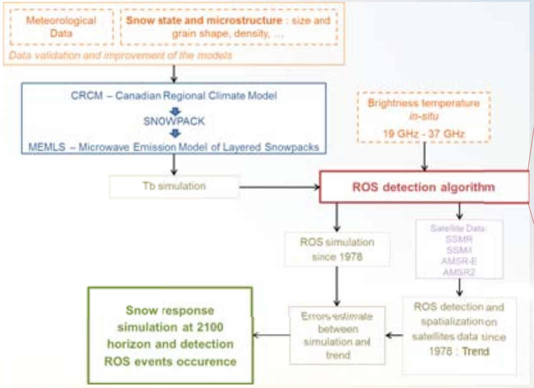
2 • Objectives

- Develop ROS detection algorithm using surface based radiometer and satellite passive microwave.
- Estimate the ROS trends until 2100 using a regional climate model and a coupled snow evolution-emission model (CRCM-SNOWPACK and MEMLS)

3 • Materials & Methods

Figure 2: Potential or confirmed sites to acquire field data





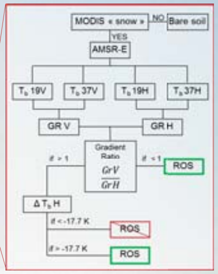


Figure 3: Research organization chart

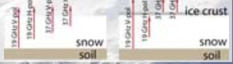
Figure 3bis: ROS extraction organization chart

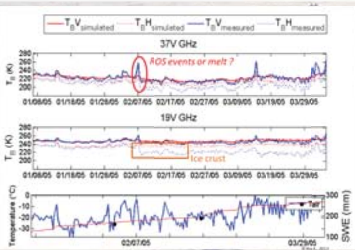
Characteristics of passive microwave observations:

- Brigthness temperature (T_b) allows for the distinction between wet and dry snow.
- Frequencies of interest are 19, 37 and 89 GHz and are available since the last 70's.
- When the snow is dry, the volume scattering generates a decrease of T_b while if the snow is wet, the brightness temperature will be given the absence of volume scattering .
- T_b (especially ratio of polarisation) are sensitive to physical variation.
- Wet snow is similar to a black body (water increasing the emmissivity).

- Deeper penetration depth at lower frequencies and V-pol.
- The lower layers of snowpack are penetrated by 19 GHz in V-pol.; and higher layers are penetrated by 37 GHz in H polarization, while these layers are also penetrated by any signal of19GHz.
- These frequencies are useful for ice crust detection, following the sporadic ROS events.
- The relationships of GR and PR results (Grenfell and al., 2008) are used to identify ROS events from passive microwaves at 19 and 37 GHz.

$$GR\,(37,19) = \frac{[Tb_{37\,GHz}(p) - Tb_{19\,GHz}(p)]}{[Tb_{37\,GHz}(p) + Tb_{19\,GHz}(p)]} \qquad PR = \frac{[Tb_V\,(37,19) - Tb_H\,(37,19)]}{[Tb_V\,(37,19) + Tb_H\,(37,19)]}$$





- Wet snow can be identified (sudden increased T_b at 37 GHz V-pol).
- After this peak the brigtness temperature decreased at 19 GHz H-pol. This phenomenon is due to the formation of ice crust.
- Depolarization of signal at 19 GHz.

Figure 4: Brithness temperature mesured (blue) and simulated (red) at 19 and 37 GHz

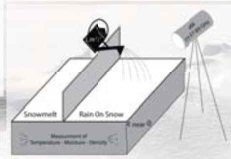


Figure 5: Next experiment to distinguish snowmelt and ROS microwave response

- *fig.5* will be performed to distinguish the snowmelt effect and the Rain On Snow.
- Radiometres are going to measure a sprayed surface (artificialy) and then a melted surface, other measurements will be made on the same snow samples to carry out simulations.

4 • Prototype Results

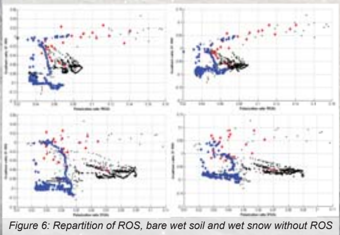


Figure 6: Repartition of ROS, bare wet soil and wet snow without ROS

AMSR-E pixels	Nbr AMSR-E passes	Observed ROS	Detected ROS (AMSR-E)	Omis-sions	Commis-sions	NAs	Accuracy
1-Salluit	258	8	8/8	0	1	5	89%
2-Kangiq.	259	7	5/7	2	0	17	71%
3-Kangirsuk	245	15	12/15	3	6	17	57%

Table 1: Validation of ROS observations and ROS detected in AMSR-E pixels (30km) in Nunavik.

- The ROS events are known for each pixels.
- According to *fig.6*, • correspond to ROS events, • are representative of bare wet soil and • correspond to wet snow without ROS events.
- The *tab.1* hilight the performances to distinguish and to detect ROS events.

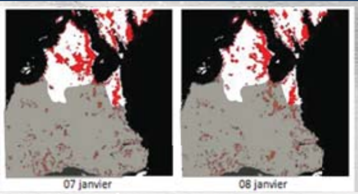


Figure 7: Spatialization of ROS events in Quebec with empirical methods

- *Fig.7* shows the repartition of ROS events during 2010 January 7th and 8th. The red zone correspond at ROS areas on these dates. The grey zone is the vegetation area which should not be taken into this research because a lot of errors caused by vegetation.
- The coast is particularly affected while the small areas into the land is affected too.

5 • Conclusions & Perspectives

- The application of ROS algorithm into the simulation of snow properties (at 2100) will allow the production of trends and an improved monitor understanding of climate change in the Arctic.
- This project aims to develop a climate change indicator *(World Climate Research Program)* to include in future predictions.
- Fields campaigns are essential because they allow us to obtain data about on variability and ROS spatial distribution

6 • Funding

- NSERC - Natural Sciences and Engineering Research Council of Canada
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- CFI - Canadan Fondation for Innovation
- Environment Canada
- Université de Sherbrooke - CARTEL

7 • Références & Contacts

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